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# THE DSN VIEWPERIODS USED FOR A MISSION

## A Look at the times when communication windows can be scheduled between the DSN and the Projects.

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**Abstract**

The Jet Propulsion Laboratory Resource Allocation, Planning and Scheduling Office (JPL-RAPSO) is chartered to allocate the limited amount of tracking hours among the various missions in as equitable allotment as can be achieved. The communication windows that can be used for communication between the ground and the Project/spacecraft are called "viewperiods." The concept of the viewperiods for (any) mission is presented in this paper, along with the levels of refinement over time (Forecasting/Project/Mid-Range/NSS) associated with those viewperiods.


## Why Look At The Viewperiods?

The viewperiods provide the basis for/specify the communications windows between the specific antennas on the Earth and the spacecraft. As such, they provide the basis upon which the specific allocations are made. The RAP (Resource Allocation Planning) process of allocating tracking coverage from the Deep Space Network's (DSN's) complement of 70m, 34m, and 26m antennas is fundamental for all missions who desire to have data collected (by their spacecraft and returned to Earth), for use by the Principal Investigators and also for dissemination of the findings/ discoveries to the public at large.

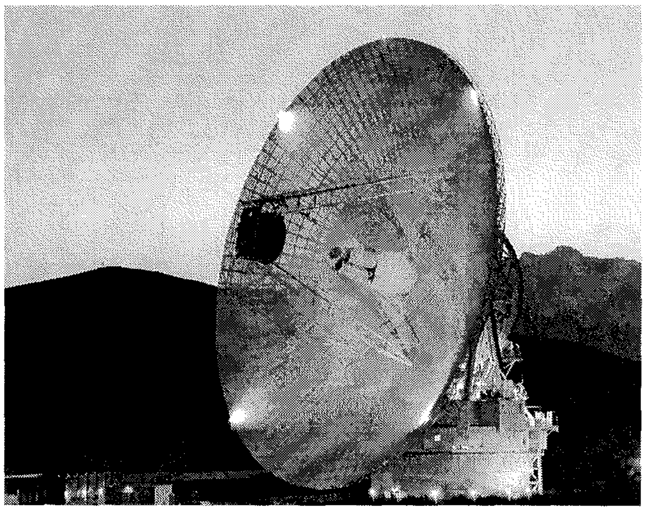

Figure 1: DSS-14 at night
70m antenna located in Goldstone

## Viewperiod Definition

A "Viewperiod" is the "period" of time that the spacecraft can be "view"ed from the antenna/tracking complex. Conceptually, this is equivalent to a person standing at the actual antenna site, and being able to look directly at the spacecraft (with no intervening obstructions, e.g., local mountains along the horizon, etc.).

## From which Antennas are the Viewperiods defined?

A Viewperiod can be defined for any antenna that is used to track spacecraft. The primary communication link utilized by JPL-RAPSO is the Deep Space Network (DSN). The DSN includes tracking stations around the world, with three primary tracking complexes (Signal Processing Centers, aka SPCs) on the Earth spread roughly 120° apart:

- Goldstone: "SPC 10", in California, USA;
- Canberra: "SPC 40", in Tidbinbilla, Australia;
- Madrid: "SPC 60", in Robledo, Spain.

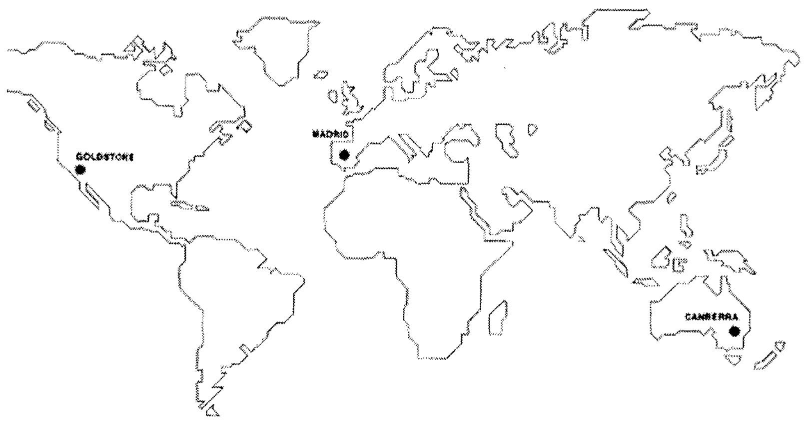


Figure 2: The location of the SPCs (primary tracking sites)

The antennas at these complexes (primarily the 70-meter and 34-meter dishes) are used to track and communicate with NASA and other Agency's deep space and near Earth missions, and allow for nearly continuous communication opportunities with spacecraft under normal conditions. This is illustrated by the case of the viewperiods for the Mars 2003 Exploration Rovers[1] presented on the next page in Figure 3:

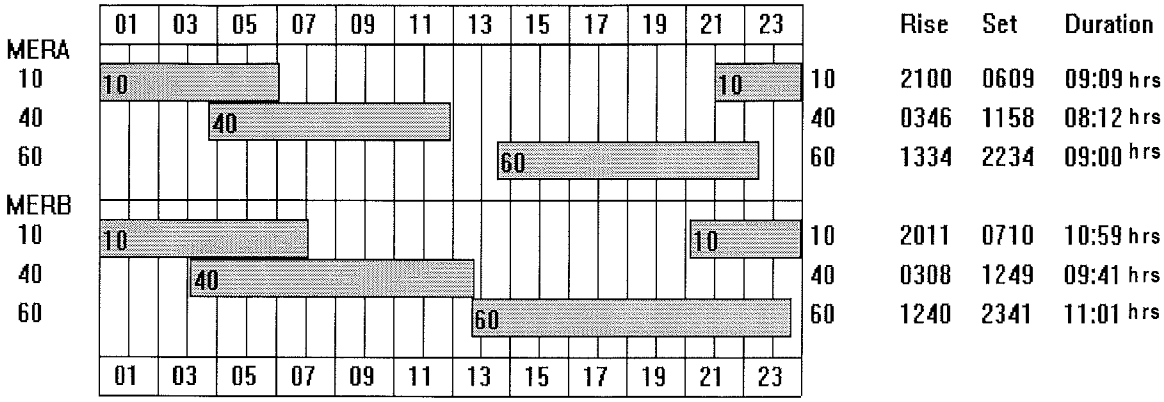


Figure 3: The tracking viewperiods for MERA and MERB on 05 Jan 2004

The exceptions to this ability for providing continuous coverage would be times when:

A) the spacecraft is geometrically "below the horizon" as viewed by all three complexes. This would occur primarily for missions that are close to the Earth (low/medium Earth orbiters; Earth Flybys, etc.) or missions that are significantly out of the plane of the Ecliptic (e.g., the Voyager 2 spacecraft, Ulysses spacecraft, other future proposed missions). Even in these instances, the SPC sites allow comprehensive tracking coverage to be achieved.

B) the spacecraft (/Project) levies tracking constraints that cause the equivalent of geometric outages. This is best illustrated (as depicted above in Figure 3) by the case of the "Project Viewperiods" for the Mars Rover A and B spacecraft. On Jan 5$^{th}$ 2004, the MERB spacecraft is still in transit to Mars, and the Project has required a ten (10) degree elevation mask (i.e. above the horizon) on the tracking antennas. With this extra constraint, it is still possible to achieve 24$^{hr}$ continuous coverage. However, the MERA spacecraft has landed on the surface, and the Project requires a twenty (20) degree elevation mask on the antennas. This has the consequence of reducing the tracking time at each complex, and further opens up the (daily) tracking "gap" from 11:58$^{hrs}$ -13:34$^{hrs}$.

## What are the viewperiods used for?

The viewperiods are used in conjunction with the individual tracking requirements for each Project so that a schedule can be constructed regarding which antennas will be tracking which spacecraft on any specific date. The viewperiods support this process by identifying which times the ground system is capable of communicating with each Project.

Continuing with the example presented above in Figure 3, it can be seen that neither MERA nor MERB would be interested in any tracking time at Goldstone/SPC 10 from 07:10$^{hrs}$ through 20:11$^{hrs}$ on the date shown. Thus, any (other) spacecraft would be able to use that tracking time (from the MERA/MERB perspective). Conversely, both MERA and MERB require tracking coverage at the same time – this "conflict" can actually be resolved by tracking MERA with the 70m antennas, and MERB with one of the 34m antennas at each site (presuming that no other Projects require the same tracking time/antenna, creating additional conflicts).

## What are the different types of viewperiods that are used in the RAPSO scheduling process?

The viewperiods used throughout the RAP Process are at one of four different levels of fidelity:

- Forecasting Viewperiods
- Project Viewperiods
- Mid-Range Viewperiods
- NSS Viewperiods.

The four different levels (Forecasting / Project / Mid-Range / NSS) exist to support different levels of accuracy/refinement, which in turn are used to support various analyses ranging from forecasting[2] the demand for tracking time based upon Project requests (which occurs years into the future), through the actual tracking of spacecraft/data return (which is occurring today). As such, each level of viewperiods will be explained it's own section:

## Forecasting Viewperiods

The Forecasting Viewperiods are designed to support the long term forecasting function that the RAP must perform. These viewperiods form the basic foundation upon which all loading analyses/studies are performed. Since this is a long-term function, the forecasting viewperiods can tolerate reasonable precision; typically this amounts to several minutes for viewperiods that tend to be ~8-10hrs in duration.

Accordingly, the definition of the Forecasting Viewperiods are specified by:

- Complex only views (SPC 10/40/60) – it is important to note that at the Forecasting Level, only the viewperiods for the generic complex exist (Goldstone, Canberra, Madrid) and never for any specific/individual antennas within the complex. This is the only viewperiod level at which viewperiods for the Complex exist; they do not exist at either the Project, Mid-Range, or NSS level.
- Elevation Mask: 6 degrees – This requirement is based upon the low elevation transmit limit for the low powered transmitter used for uplink to the spacecraft.
- Duration – Forecasting viewperiods generally begin on the first day of the mission, and run until the end of the end of the prime (or extended) mission date. In cases where the mission is already flying, the viewperiods might actually begin with today's date instead of the launch date. (Example: There is little point in updating the Venus Flyby viewperiods for the Cassini Mission, since that event has already occurred, and those viewperiods will not be used in any of the current/future analyses.)
- Frequency of Update – the Forecasting Viewperiods are required to be verified/updated a minimum of twice a year, in support of the semi-annual Resource Allocation Review Board (RARB). If the verification shows no change, then file redeliveries are not required. (Example: Cassini is currently between Jupiter and Saturn, and since there was no change in the trajectory, no update was required for the Feb 2002 RARB.) As significant trajectory changes occur (e.g., use of a different launch window), updates are requested as soon as that change becomes the new official Project/ Mission Baseline.

Forecasting Viewperiods are intended to be used solely for that purpose: Forecasting. In some cases, the Forecasting Viewperiods could be used to support later steps the scheduling process with sufficient fidelity: one example of this would be the case of viewperiods for deep space missions, such as Cassini, illustrated in Figure 4. In the current Forecasting Trajectory, the actual Saturn tour is represented by a generic orbit around Saturn. As viewed from the actual antennas themselves, while the Doppler and Telemetry will be quite different depending upon the actual tour selection, the times of the viewperiods will remain constant (a spacecraft position change of three million miles would result in a viewperiod change of less than one minute).

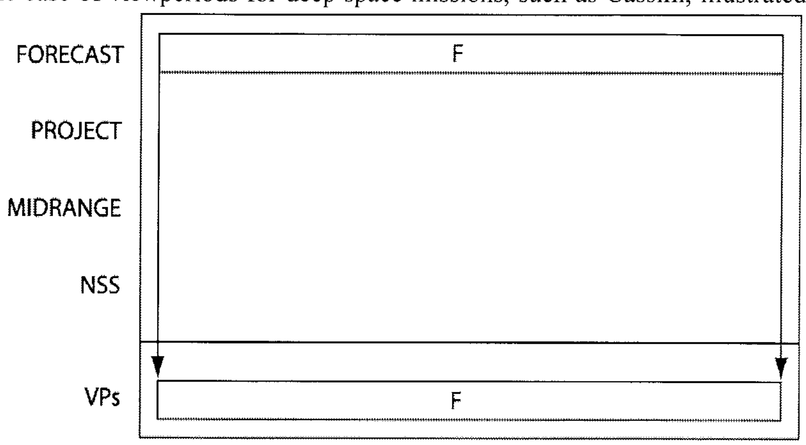


Figure 4: When Forecasting Viewperiods are Used.

In other cases, it is completely inadequate to use Forecasting Viewperiods for scheduling. An example of this is the Chandra Mission, which is an Earth orbiting spacecraft. The Forecasting viewperiods were generated by taking the post-deployment state vector (which occurred in June of 1999) and then that state vector was propagated (orbiting the Earth) for a duration of ten years. Incremental (mathematical rounding and/or actual gravity field modeling) errors accumulate and compound over those ten years. This propagation was performed so that the "flavor" of the Chandra tracking requirements could be represented in future loading studies; however, the difference between the Forecasting viewperiods and the NSS viewperiods in August of 2001 was ~3-4 hours in viewperiod start times.

This explains the need for additional levels of viewperiod refinement (Project, Mid-Range, and NSS) which provide the appropriate/higher level of fidelity necessary to support the analyses and scheduling performed. The next level of resolution is referred to as "Project" viewperiods:

## Project Viewperiods

The Project Viewperiods, as might be implied by the name, are viewperiods which are provided by the project itself for the specification of the tracking time which meets that Project's particular needs. These Project Viewperiods are designed to be an adjunct to the Forecasting Viewperiods, providing the extra specification for the viewperiods that is not reflected by the definition of the Forecasting Viewperiods. An example of this is the Goldstone Solar System Radar (GSSR) Project, which among other objectives, uses the high power transmitter on the 70-meter antennas to make observations of Earth approaching asteroids. As uplink rules (without the appropriate waivers/approval) restrict high power transmission times to when the antenna is pointed twenty degrees (or higher) above the horizon, it can be seen that the Forecasting Viewperiods would not accurately represent the tracking time needed for these observations.

The actual definition of the Project Viewperiods is as follows:

- Antenna specific views (e.g., DSS-14) – it is important to note the Project Level viewperiods are for specific/individual antennas, (the 70m antenna at Canberra, "DSS-43"), and incorporate the actual location and altitude unique to that individual antenna. Project Viewperiods do not exist for the generic complex (Goldstone, Canberra, Madrid).
- Elevation Mask: (variable) – This is the primary attribute to the Project Viewperiods: the elevation mask at the individual antennas is left to the Project to set as they know best; examples would be a fixed elevation mask of twenty degrees, ten degrees, actual horizon mask, or other value.
- Duration – The duration covered by these Project supplied Viewperiods is of a specification that is acceptable to the project itself; Project viewperiods begin, and end, at the Project's sole discretion. (Examples: The GSSR observations of the asteroid 1998SF36 are scheduled from June 20-25, 2004; the Mars Exploration Rovers use a 10 degree elevation mask from launch until Mars arrival, and a 20 degree elevation mask for Mars Surface Operations.)
- Frequency of Update – the Project Viewperiods are updated by the Project at intervals which they deem appropriate. The requirement is that the Project Viewperiods are verified twice a year, in support of the semi-annual RARB. If the verification shows no change, then file redeliveries are not required.

In the hierarchy of viewperiods, as shown in Figure 5, if Project Viewperiods exist, they will be preferentially used rather than Forecasting Viewperiods. In situations where Project Viewperiods do not exist, Forecasting Viewperiods will be used.

In practice, the Project Viewperiods can introduce a level of flexibility that is not available through the use of the standard Forecasting Viewperiods. To illustrate this use of viewperiods to express project requirements, the case of the Mars Express (MEX) Mission is presented.

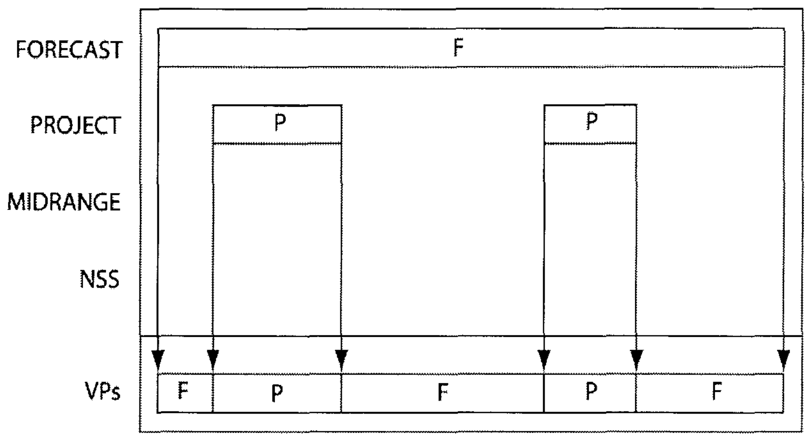


Figure 5: Project Viewperiods Take Precedence over Forecasting VPs.

Mars Express is an European Space Agency mission, which has priority access to the Perth 64m Antenna in Australia (on the western side of the continent), and therefore would naturally want DSN support at times that the Perth Antenna cannot track the MEX spacecraft. One effective method of implementing this requirement is through the use of the Project Viewperiods. The Forecasting Viewperiods can be edited to remove concurrent tracking time with the Parkes antenna, and entered as antenna specific (DSS-14, 43, 63, etc.) Project viewperiods, effectively blocking the usage of the Forecasting Viewperiods, and resulting in the full implementation of the exact tracking requirements as expressed by the Mars Express Mission.

## Mid-Range Viewperiods

The Mid-Range Viewperiods are a precise determination of the actual viewperiods propagated out into the future for a rolling duration of (a minimum of) two years from the current date. The Mid-Range viewperiods support the RAPSO function of initial scheduling/placement of tracking passes for all the spacecraft/missions requesting coverage. As such, the Mid-Range Viewperiods are required inputs for all missions requesting tracking coverage within two years from today's date. The definition of Mid-Range Viewperiods is specified by:

- Antenna specific views (e.g., DSS-14) – the Mid-Range Level Viewperiods are for specific/individual antennas, (the 70m antenna at Madrid, "DSS-63"), and incorporate the actual location and altitude unique to that individual antenna. Mid-Range Viewperiods are not associated with the generic complex (Goldstone, Canberra, Madrid).
- Elevation Mask: (actual ground terrain/horizon obstructions) – This is the primary attribute to the Mid-Range Viewperiods: these viewperiods are highly accurate predictions of precisely when the spacecraft can be tracked by the individual stations, from horizon to horizon.
- Duration – The duration covered by these Mid-Range Viewperiods is of a specification that is acceptable to the Project itself; providing that the minimum duration of a rolling timeframe of two years from today's date is satisfied.
- Frequency of Update – the Mid-Range Viewperiods are updated at intervals deemed appropriate by the Project. Provided that there are currently two years of Mid-Range Viewperiods in the system for the Project, there is no requirement to force an updated delivery.

In the hierarchy of viewperiods, if Mid-Range Viewperiods exist, they will be preferentially used rather than either Project or Forecasting Viewperiods, as shown in Figure 6.

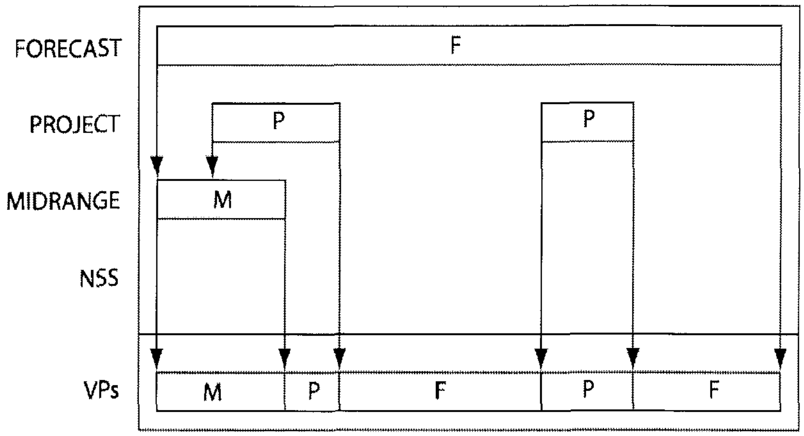


Figure 6: Illustration of Mid-Range Viewperiods.

In application, the Mid-Range Viewperiods tend to be a two-year (and longer) propagation of the same inputs that are used to generate the NSS Viewperiods for the spacecraft/mission. Updates therefore could be performed each time the NSS viewperiods are updated, depending upon Project preferences. An automated script checks the file server daily for updated file deliveries; if one is found, it is automatically processed and loaded into the system so that the updated viewperiods can be used by the RAPSO scheduling team.

Although Mid-Range Viewperiods are highly accurate, there is a need for precise viewperiods updated on a regular basis to support the final scheduling of tracking passes to be executed by the antennas, which provides the need for the NSS viewperiods.

## NSS Viewperiods

The NSS Viewperiods (which are generated by the Network Support Subsystem of the Jet Propulsion Laboratory) are the ultra precise viewperiods for the spacecraft. These are generated on an antenna-by-antenna basis, and include the station location and the actual terrain mask. Additional parameters (/comments) designed to support the flight team in the real time operation of the spacecraft (one way light time, round trip light time, Doppler frequency shift of the spacecraft's radio frequency as observed at the specific antenna, and others) are also included in the NSS file. The definition of the NSS Viewperiods is:

- Antenna specific views (e.g., DSS-14) – the NSS Level Viewperiods are for specific/individual antennas, (the 70m antenna at Canberra, "DSS-43"), and incorporate the actual location and altitude unique to that individual antenna. NSS Viewperiods do not exist for the generic complex (Goldstone, Canberra, Madrid).

- Elevation Mask: (actual ground terrain/horizon obstructions) – This is the primary attribute to the NSS Viewperiods: these viewperiods are precise predictions of when the spacecraft will be in view at each antenna which will be supporting/providing tracking coverage for that spacecraft/mission.
- Duration – The duration covered by these NSS Viewperiods is a rolling timeframe that covers up to eight weeks into the future from today's date.
- Frequency of Update – the NSS Viewperiods are typically updated/regenerated by the Flight Project for the Mission on a weekly basis. For earth orbiters, weekly updates are required for three weeks through Real Time (today's date).

The NSS Viewperiods will be preferentially used rather than any other Viewperiods, as shown in Figure 7.

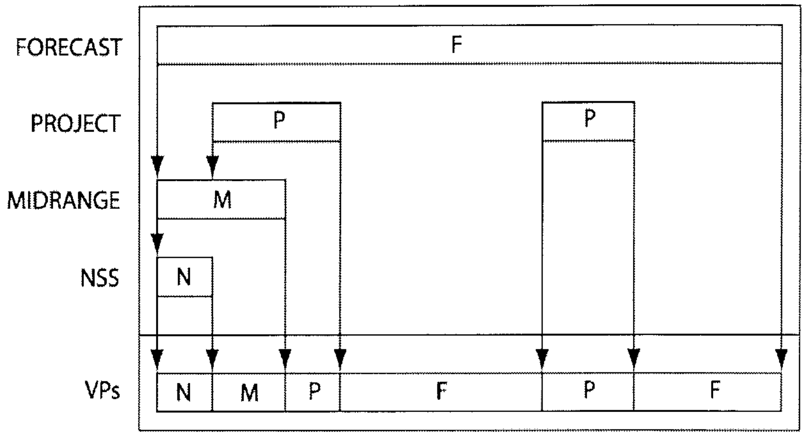

Figure 7: The Priority of NSS Viewperiods is ultimate.

In very *rare* instances, NSS will actually generate viewperiods that span further into the future than the specified eight weeks. This happens on an exception basis, and requires some very special circumstances: a spacecraft which is not performing any trajectory changes, won't be occulted (planetary flybys), and is not in the vicinity of any gravitational sources. Given this, it is understandable that at the current time, extended NSS viewperiod predicts exist only for the Voyager 1, Voyager 2, Ulysses, and Cassini Missions.

## Summary

The purpose of the Viewperiods is to support the RAPSO office in producing Loading Studies, Analyses, Forecasting Projections, and Schedule of Antenna Tracking Times. The system that is in place uses four different quality levels of viewperiods (Forecasting, Project, Mid-Range, and NSS). This provides for the appropriate level of accuracy necessary to achieve these purposes, and optionally provides the ability to incorporate higher fidelity viewperiods at earlier stages in the process.

References:

1. Sauter, Luke M., and Kehrbaum, John M., "Mars Surface Direct Communication", AIAA 2001-4776, AIAA Space 2001 Conference and Exposition, Albuquerque, New Mexico, August 28–30, 2001.

2. N. Lacey and D.G. Morris, "JPL RAPSO Long Range Forecasting", AAS 02-223, 12th AAS/AIAA Space Flight Mechanics Meeting, San Antonio, Texas, January 27-30 2002.